VOLUME XLI NUMBER 2 WHOLE NUMBER 361

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PUBLISHED MONTHLY
(Ten numbers per year)

February, 1947

PRINTED FOR THE SOCIETY
TORONTO: 3 WILLCOCKS ST.

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Address of Editors: David Dunlap Observatory, Richmond Hill, Ontario.

Business correspondence, remittances, etc., should be addressed to J. H. Horning, Treasurer of the Society, 3 Willcocks St., Toronto 5, Ontario.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.

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PRINTED IN CANADA

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SIR JAMES JEANS: AN APPRECIATION*

By RALPH E. WILLIAMSON

ON September 16, 1946, less than a week after his 69th birthday, James Hopwood Jeans died at his home in Dorking, England. His passing was a real loss to all those who are interested in astronomy, because few men have equalled Jeans in ability to discover scientific truth; perhaps no one was a clearer interpreter of it than he.

In 1896, Jeans, the son of a parliamentary journalist, went up to Trinity College, Cambridge. Two years later, when he took the Mathematics Tripos at the age of 21, he placed as second wrangler. In his fourth year at Cambridge, he was elected Isaac Newton Student. In 1904, he became a university lecturer in mathematics, but left Cambridge the next year to accept a professorship of applied mathematics at Princeton University in the United States. In 1910, he returned to Cambridge as Stokes Lecturer in mathematics. Here he remained until in 1929, after twenty-five years of teaching, research, and service to learned societies, he retired to his home at Dorking, in Sussex. But retirement merely meant a change of occupation for him. Instead of conducting his own researches, he now turned his energies to interpreting scientific discovery to the non-scientist.

The current trend of physics—and in particular astrophysics—has been profoundly influenced by Jeans's original researches, and his authoritative monographs. His books on dynamics, on the kinetic theory of gases, and on electromagnetic theory are standard works in their fields. In 1914, when the quantum theory of matter was by

*Lecture before the Toronto Centre.

no means universally accepted, Jeans drafted a "Report on Radiation and the Quantum-Theory" for the Physical Society of London. At that time, quantum mechanics and wave mechanics, in the sense that we now know these powerful analytical tools for investigating matter and radiation, were not really known. Yet the maturity of the judgments made in his report on the quantum theory was such that even now, any evaluation of quantum mechanics must to a considerable extent be a repetition of what Jeans said in 1914.

It is far too soon for us to know the real value of Jeans's contributions in theoretical astrophysics. But much of his work cannot fail to be of considerable importance for a long time to come. He was interested in the theory of stellar structure, and he contributed much to our knowledge of the absorption and emission of radiation in the interiors of stars. He developed a complete theory of rotating and pulsating stars. His researches on the stability and the evolution of single stars and binary stars are classics, and his papers on the origin of the solar system are required reading in that highly controversial field. Another field of astrophysics to which Jeans contributed heavily is stellar dynamics, that discipline which treats of the positions and motions of stars in large aggregations, such as galaxies. He showed, for example, that collisions, and even near approaches of stars as they move about in space, must be events of unimaginable rarity. A remarkable physical statement known as "Jeans's Theorem" was long the corner-stone of mathematical discussions on stellar dynamics. In particular, Lindblad has devoted many years to exploring the important consequences of the theorem in interpreting the spiral shapes of the extra-galactic nebulae.

It is pleasant to be able to say that the widespread appreciation of Jeans's work was made abundantly evident to him during his life. In 1906, almost at the beginning of his career, he was elected a fellow of the Royal Society, and in 1919, he became its secretary. This responsible post was his for ten years. He was two years president of the Royal Astronomical Society, and for one year served as president of the British Astronomical Association. He was knighted in 1928, the year in which his important book "Astronomy and Cosmogony" was published. In 1939, he was awarded one of the highest honours which the King can bestow on a subject for eminence in

the fields of science and letters: he became one of the twenty-four British members of the Order of Merit. He held honorary doctor's degrees from many educational institutions, among them Oxford, Manchester, Aberdeen, St. Andrew's, Dublin, and Johns Hopkins.

When Jeans retired to Dorking in 1929, he commenced a phase of his work for which he will perhaps be longest remembered and appreciated. I refer, of course, to his so-called "popular" books: "The Universe Around Us", "The Stars in their Courses", "The New Background of Science", and many others, which have brought the fascination of astrophysics within the reach of all. The shaky bindings and the well-thumbed pages of the average circulating-library copy of Jeans's books are proof enough of their popularity.

The picture of the universe as presented by Jeans, is for the most part as accurate as we know how to make it; and there is little doubt that his descriptions approach the ultimate in clarity and charm. His ability to present the abstruse or the incomprehensible in terms of the familiar, is perpetually fascinating. When he had occasion to refer to the total number of spiral nebulae in the universe, he might have merely said, "There are one hundred billion of them", and left his reader with only a hazy feeling of bigness. How forceful was his way of amplifying that bare statement: "We may visualize the total number of nebulae in the whole of space as equal to the number of raindrops in a heavy shower—perhaps one giving a tenth of an inch of rainfall over the City of Oxford."

He well knew that it is not enough merely to impart information. Just saying that the star-density in our galaxy is one-tenth the solar mass per cubic parsec utterly fails to convey the true fact of the emptiness of space. But we begin to understand, when Jeans says: "Empty Waterloo Station of everything except six specks of dust, and it is still far more crowded with dust than space is with stars." Such neat and pointed metaphor literally puts the universe within the grasp of our minds.

We must all agree that the fundamental importance of science is the intellectual and spiritual satisfaction it gives to human beings. But science is rapidly becoming so specialized a discipline that it is in danger of becoming the unique possession of the few with technical training, merely because of the prohibitive amount of training

required for a complete understanding. But as soon as science fails to be understood and appreciated by many, its main purpose ceases to be fulfilled. The only practicable solution to this problem lies in the descriptive writings of some person who can authoritatively translate the jargon of the laboratory and of the observatory into clear and forceful language. There can be no doubt that Sir James Jeans was a most able interpreter of that inspiring realm of human discovery to which this Society is dedicated.

If we ever have any doubts as to the worth of astronomy, or as to its place in human society, I think we can derive complete reassurance from Jeans's assessment of the meaning of astronomy. He says:

> ...we are living at the very beginning of time. We have come into being in the fresh glory of the dawn, and a day of almost unthinkable length stretches before us with unimaginable opportunities for accomplishment.
>
> Our descendants of far-off ages, looking down this long vista of time from the other end, will see our present age as the misty morning of the world's history; our contemporaries will appear as dim heroic figures who fought their way through jungles of ignorance, error and superstition to discover truth, to learn how to harness the forces of nature, and to make a world worthy for mankind to live in.
>
> We are still too much engulfed in the greyness of the morning mists to be able to imagine, however vaguely, how this world of ours will appear to those who will come after us and see it in the full light of day. But by what light we have, we seem to discern that the main message of astronomy is one of hope to the race and of responsibility to the individual—of responsibility because we are drawing plans and laying foundations for a longer future than we can well imagine.

David Dunlap Observatory,
Richmond Hill, Ontario.

THE TWENTY-FIFTH ANNIVERSARY OF THE LONDON CENTRE OF THE R.A.S.C.

By H. R. Kingston

THE London Centre of the R.A.S.C. celebrated its silver anniversary on January 10, 1947. The celebration consisted of two parts. The first was an informal dinner in the Cafeteria of the University of Western Ontario at 6:15 p.m., at which 41 members, including four charter members, and guests were present. This function provided an opportunity to renew happy associations and to meet the guest speaker, Dr. Helen Sawyer Hogg, Astronomer at the David Dunlap Observatory of the University of Toronto.

The second feature of the evening was the meeting at the Hume Cronyn Memorial Observatory, where over sixty gathered for the programme under the chairmanship of the President of the London Centre, Dr. A. J. Watt. The occasion was honoured by the presence of Mr. and Mrs. D. C. Bawtenheimer, who arrived at 8:15 from the Windsor Centre to be present at the meeting. This was a very happy surprise and our only regret was that they had to leave early to get a train for home.

The first item on the programme was the reading by the Secretary-Treasurer, Mr. A. Emsley, of the minutes of the first meeting of the London Centre held in January 18, 1922. This was followed by a roll call of the 32 charter members, four of whom were present, namely Mr. T. C. Benson, Mrs. W. J. Knox, Mrs. (Dr.) S. R. Moore, and Dr. H. R. Kingston.

The lecturer of the evening, Dr. Hogg, was then introduced. She is a graduate of Mount Holyoke College and of Radcliffe College, Harvard University. She has been on the teaching staffs of several colleges and is at present lecturing at the University of Toronto. She has carried on research at Steward Observatory of the University of Arizona, the Dominion Astrophysical Observatory at Victoria and the David Dunlap Observatory of the University of Toronto. In addition to being a successful homemaker with three children, she has succeeded in doing more research on variable stars in star clusters than any other astronomer. For her outstanding work in this field she was elected to membership in the Physical Science Section of the Royal Society of Canada, the first woman to be so honoured.

Dr. Hogg congratulated the London Centre on its twenty-five prosperous years and emphasized the importance of such centres in the development of astronomy. She then gave a masterly, though mostly non-technical, address on "Beacons of the Milky Way". She referred first to the solar system where 99.9% of the total mass was concentrated in the sun. It has been estimated that the sun can continue to radiate from 10,000 to 30,000 million years. Someone has facetiously remarked that this stupendous feat is possible because the sun never stays out at night and therefore conserves its energy. Our sun is but one of millions of suns making up our Galaxy or Milky Way, which has the form of a lens or grindstone 100,000 light-years in diameter. Our sun is about 25,000 light-years from the centre of the Milky Way and revolves around this centre in somewhat over 200,000,000 years. The gigantic systems of hundreds of thousands of stars, which we call globular clusters, outline our Milky Way and can be seen to greater distances than any other individual objects belonging to it. There are a hundred such clusters known, one third of which lie in the important Sagittarius-Scorpio region of the heavens, indicating that the distant centre of our galaxy is there too. Individual clusters are found to distances of fifty thousand light-years above or below the galactic plane. The problem of determining distances within our galaxy is made complicated by the enormous amount of absorbing material present, concentrated toward the central plane of the Milky Way, or the type of the nebulosity found in the great nebula in Orion or the S nebula in Ophiuchus. This absorbing material is now thought to equal in mass all the thousands of millions of stars in our galaxy, and is proving of more and more importance in the observation and theoretical ideas of our Milky Way system. An interesting lantern slide compared two photographs of the Milky Way in the region of Sagittarius, one an ordinary picture and the other taken on an infra-red plate. The increased detail shown on the latter was most striking and suggestive of the possibility of further penetration toward the centre of the Milky Way. It would be easier to visualize our galaxy to-day if we could get off some hundreds of thousands of light-years and look back on it. Then it might have the appearance of the Andomeda Nebula as we see it to-day. The lecture was illustrated with numerous excellent lantern slides.

Greetings and congratulations were read from various Centres across Canada and also from some members of the London Centre who were unable to be present.

The programme concluded with a brief address entitled "Twenty-five Years in Retrospect" by Dr. H. R. Kingston. He told how the possibility of forming an astronomical study group in London was broached by a few persons at the close of an illustrated lecture on "The Wonderful Heavens" given by himself in the old Public Library on January 5, 1922. As a result of this, a meeting was held on January 18 in Western University (Huron College) where it was decided to form a local association and to hold meetings on the second Friday night of each month. It was also decided to ask permission for the group to become the London Centre of the Royal Astronomical Society of Canada. This was granted in due course and the London Centre was launched with thirty-two charter members. The officers elected for the first year were: President—Dr. H. R. Kingston, Vice President—Miss Grace Blackburn, Secretary-Treasurer—Dr. E. T. White, Council—Rev. R. J. Bowen, Mr. H. B. Hunter, Mrs. (Dr.) S. R. Moore, Mr. J. C. Middleton and Mr. W. A. McKenzie.

During the past 25 years the Society has carried on without interruption. The meetings were held in Western University until it moved to its new site when it was decided to meet in the Public Library. Later the Society was provided with excellent accommodation in the new London Life Building and later still it met in the Normal School. Since October, 1940, it has been privileged to hold its meetings in the Hume Cronyn Memorial Observatory of the University of Western Ontario, where the 10-inch refracting telescope has been available for observations. The programmes have been largely semi-popular in nature and have been greatly aided by a number of models, demonstrating instruments and telescopes made or purchased by the members of the Centre and by a fine 4-inch refractor loaned and later generously presented to the Society by the late Dr. W. E. Saunders. Since astronomy is closely associated with mathematics, physics, chemistry, geology and geography, lectures in these fields have from time to time been given by members of the Science Departments of the University of Western Ontario. Also one lecture was given by the English Department on the topic

"Astronomy in Literature". The Society has brought a number of outside speakers to the City, including the late Sir Frederick Stupart, Dr. Frank S. Hogg, Dr. C. A. Chant, Dr. P. M. Millman, Dr. J. A. Pearce, Dr. A. E. Johns, Dr. J. F. Heard, Dr. S. A. Mitchell, formerly Director of the Leander McCormick Observatory of the University of Virginia, and others.

The speaker recalled some of the activities of the Centre, for example, public observations with telescopes; several public observations of total lunar eclipses; co-operation with the Western Ontario Federation of Naturalists; the observation of the transit of Mercury on May 7, 1924, when in spite of warnings, one man almost succeeded in getting a direct peek through the telescope at the sun; co-operation in Dr. Millman's nation-wide observing of metors in programmes organized by Mr. John Middlebrook, on one of which the observers were rewarded by seeing also a very spectacular display of coloured northern lights; and the total solar eclipse expedition to Louiseville, Quebec, on August 31 1932, On this occasion a single tiny cloud in a deep blue sky made necessary, at almost the last minute, a quick shift of a few rods by our party of 50 or 60, who then had an excellent view of the spectacle.

Individual activities of the Centre included the construction of a number of excellent reflecting telescopes by several members and the designing and building, by Mr. W. G. Colgrove and others, of a number of very efficient models and instruments for demonstrating astronomical phenomena. For this contribution to the teaching of astronomy Mr. Colgrove was awarded the Chant medal of the R.A.S.C. for 1942. The speaker closed by stating that he felt that the past 25 years of astronomical activity had not only added much to the knowledge of the skies on the part of the members but had brought much satisfaction and happiness to a large number of citizens, and that the Centre would continue to add to the culture of the Community by bringing about an ever-finer appreciation of what the heavens are telling.

Hume Cronyn Memorial Observatory,
University of Western Ontario,
London, Ontario.

CURVES OF GROWTH FOR STARS OF CLASS F DETERMINED FROM LINES OF NEUTRAL IRON*

By K. O. WRIGHT

ABSTRACT

Curves of growth for neutral iron lines in the spectrum of α Persei have been plotted after all measurable lines had been separated into groups of about half a volt in excitation potential, χ_i. It has been found necessary to introduce a new variable—the turbulent velocity, v—in order to fit the observed curves on to theoretical curves as calculated by Menzel and by Unsöld. The turbulent velocity is found to vary from 7.0 km./sec. for $\chi_i = 0$ volts to 3.6 km./ sec. for $\chi_i = 4.6$ volts, and this range is believed to be greater than any errors of measurement. A slight extension of the theory permits a variation of v with χ_i and this has been used to determine an excitation temperature from neutral iron lines. Similar observations for other stars of class F have been used to study this relation and in each case the turbulent velocity has been found to vary with excitation potential. Excitation temperatures derived in this way are somewhat higher than those derived when v is held constant, but they are usually lower than the effective temperatures of the stars. This effect suggests that there may be some stratification in the atmospheres of these stars, even for atoms of the same element.

INTRODUCTION

During an analysis of line intensities in the spectra of solar-type stars, curves of growth were constructed for all atoms for which numerous lines could be measured in the region λλ3700-6750. As there were considerably more lines of neutral iron available for study than for any other atom, these intensities were investigated in some detail. The lines were grouped into ranges of about half a volt in excitation potential and, for each line in a group, the intensity, represented by log (W/λ), was plotted against the solar log X_f-value, which is proportional to the number of atoms producing the line. Theoretical curves of growth, calculated according to the theory of Menzel[1] and Unsöld[2] were fitted onto these plots. In order to obtain satisfactory agreement between curves and plotted points, it was found necessary to decrease the value for the turbulent

[1] *Ap. J.*, vol. 84, p. 462, 1936.

[2] *Physik der Sternatmosphären*, p. 264, Springer, Berlin, 1938.

Contributions from the Dominion Astrophysical Observatory, No. 6.

velocity as the excitation potential increased. This result may prove to be important in the further development of the theory of curve-of-growth phenomena and in the study of stellar atmospheres. As the Victoria measures of line intensities in the spectrum of α Persei are believed to be as accurate as those available at the present time for any other star (with the exception of the sun), these observations are discussed in some detail. The results for other stars are also presented.

Victoria Measures for α Persei

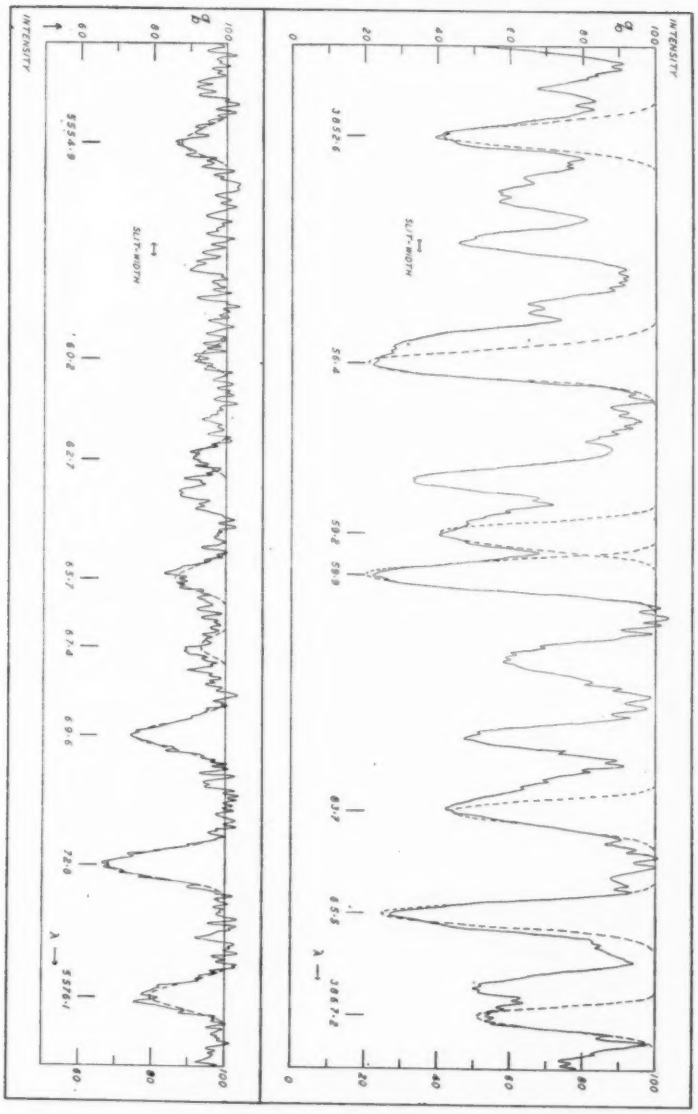
In a previous Contribution[3] it was noted that intensities of 325 lines of neutral iron have been measured on high-dispersion spectra of α Persei in the region λλ3700-6750. Second and third orders of a Wood grating were used in the Littrow form of the Victoria spectrograph; these instruments give dispersions of 7.0 and 4.4 A./mm. respectively for the regions λλ5150-6750 and λλ3700-4500. The three-prism spectrograph was also used for the region λλ4020-5600. Equivalent widths were obtained from planimeter measures of intensitometer tracings. Profiles of both strong and weak lines of neutral iron in the spectrum of α Persei are shown in figure 1. The upper tracing shows the spectrum, taken with the third order of the grating, from λλ3851-3868; the lower tracing, taken with the second order, covers the region λλ5552-5578. Tracings made with

Fig. 1. Intensitometer Tracings of the Spectrum of α Persei, Showing Profiles of Neutral Iron Lines.

The upper tracing, taken with the third order of a Wood grating, shows the region λλ3851-3868. The original tracing increased the dispersion of the spectrum two hundred times to 4.5 cm./A. The position of the continuous spectrum (intensity = 100) was derived from regions almost free from lines between λ3750 and λ3920, including that at λ3860 shown here. The lower tracing, taken with the second order of the same grating, covers the region from λλ5552-5578. The original dispersion of the tracing was 2.9 cm./A. In this portion of the spectrum, there are fewer lines and the continuous spectrum is easily determined.

Note that the higher resolving power of the upper tracing makes the observed width of the lines (in Angstroms) appreciably less than those in the lower diagram, although the lines are intrinsically stronger. In each case they are appreciably wider than the spectrograph slit.

[3] *Cont. Dom. Ap. O.* No. 2; J.R.A.S. C., vol. 40, p. 183, 1946.


INTENSITY
SLIT-WIDTH
λ
5554·9
6·02
6·27
6·57
6·74
6·95
7·18
5578·1
INTENSITY
SLIT-WIDTH
λ
5524·6
5564
5584
5604
6547
6562·8

the intensitometer, which was designed by Beals,[4] place the continuous spectrum on a straight line across the sheet at the position representing an intensity of 100 per cent.; thus the same regions of the spectrum taken on different plates may be superposed. The line profiles shown as broken lines in figure 1 are the average of two such spectra in each case and were drawn after allowance for any blending with other lines had been made. These are observed profiles; no attempt has been made to correct for the resolving power of the spectograph. Such a correction would make the lines deeper and somewhat narrower, but the total area (or equivalent width) would remain the same. It may be noted that there is little or no evidence of wings in the strong lines of α Persei, though the same lines in the solar spectrum have broad wings. This indicates that the shapes of the lines in α Persei are not produced by radiation, or collisional damping to any great extent, but, in all probability, are produced by Doppler motions of the atoms.

The lines in the spectrum of neutral iron have been classified almost completely by Russell and Moore;[5] additional data are given in Miss Moore's *Revised Multiplet Table*.[6] The absorption lines measured in α Persei arise from energy levels within the atom ranging from 0 to 4.8 electron volts. In a stellar atmosphere which, for purposes of the simple theory, is considered to be in thermodynamic equilibrium, the number of atoms in each level follow a Boltzmann distribution which is exponential in character, according to the formula

$$N_i = N_0 e^{-\chi_i/kT} \qquad (1)$$

where N_i is the number of atoms in the level with excitation potential χ_i, N_0 is the number of atoms in the ground state ($\chi_i = 0$), and k is the Boltzmann constant. The number of atoms in the higher levels decreases very quickly as the excitation potential χ_i increases, but it increases with the excitation temperature T.

The iron lines measured in α Persei were separated according to excitation potential into ten groups, each having a range of about half a volt. All lines in the ranges 0.86-1.01, 2.68-3.03 and 4.06-4.42 volts have been plotted in the three sections of figure 2. For each

[4] *J.R.A.S. C.*, vol. 38, p. 65, 1944.
[5] *Tr. Am. Phil. Soc.*, vol. 34, p. 111, 1944.
[6] *Cont. Princeton O.*, no. 20, 1945.

line, log W/λ has been plotted against log X_f, where W is the measured equivalent width of the line and λ is the wave-length, both measured in Angstrom units; log X_f is derived from a curve of growth for the sun similar to that described elsewhere[7] except that the slope of the damping portion of the curve has been adopted as 0.6 rather than the theoretical value of 0.5. The solid curve shown in figure 2 is a theoretical curve of growth which has been superposed on the observations in the position which gives the least deviation of the plotted points from the curve.

According to the theory developed by Menzel,[1] log $(W/\lambda.c/v)$ is a function of log X_0, where X_0, the optical depth at the centre of an absorption line is given by

$$X_0 = \frac{\sqrt{\pi}e^2}{mc} \quad \frac{N_a}{b(T)} \; g_i f \lambda \; . \; \frac{1}{v} e^{-\chi i/kT} \qquad (2)$$

N_a is the total number of atoms in a given stage of ionization, and refers to neutral iron in this paper; $b(T)$ is the partition function which changes very slowly with temperature; $g_i f$ is proportional to the laboratory strength of the line; and the other quantities not defined elsewhere are universal or atomic constants. For very weak lines $W/\lambda.c/v$ is proportional to X_0, and therefore to N_i, the number of atoms producing the line, but for very strong lines it is proportional to $\sqrt{X_0}$, and also to $\sqrt{\Gamma}$, where Γ is the damping factor. Although the intensity of a line is represented by W/λ, the factor c/v appears in the theoretical expression relating total intensity of the line to its optical depth whether it is produced by Doppler motions of the atoms or by radiation or collision damping. In the elementary theory, v is the most probable velocity of the atoms at temperature T as given in the kinetic theory of gases; in this paper it represents the combined velocity produced by thermal motions of the atoms and turbulent motions such as were postulated by Struve and Elvey[8] to explain curve-of-growth phenomena for supergiant stars, and is called the turbulent velocity.

Menzel[9] and Unsöld[2] have published families of curves which represent the relation between $W/\lambda.c/v$ and X_0 for all intensities

[7] *Ap. J.*, vol. 99, p. 249, 1944.
[8] *Ap. J.*, vol. 79, p. 409, 1934.
[9] *Pop. Astron.*, vol. 47, p. 66, 1939.

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According to the theory developed by Menzel,[1] log $(W/\lambda.c/v)$ is a function of log X_0, where X_0, the optical depth at the centre of an absorption line is given by

$$X_0 = \frac{\sqrt{\pi}\epsilon^2}{mc} \quad \frac{N_a}{b(T)} \; g_i f \lambda \,.\, \frac{1}{v} e^{-\chi_i/kT} \qquad (2)$$

N_a is the total number of atoms in a given stage of ionization, and refers to neutral iron in this paper; $b(T)$ is the partition function which changes very slowly with temperature; $g_i f$ is proportional to the laboratory strength of the line; and the other quantities not defined elsewhere are universal or atomic constants. For very weak lines $W/\lambda.c/v$ is proportional to X_0, and therefore to N_i, the number of atoms producing the line, but for very strong lines it is proportional to $\sqrt{X_0}$, and also to $\sqrt{\Gamma}$, where Γ is the damping factor. Although the intensity of a line is represented by W/λ, the factor c/v appears in the theoretical expression relating total intensity of the line to its optical depth whether it is produced by Doppler motions of the atoms or by radiation or collision damping. In the elementary theory, v is the most probable velocity of the atoms at temperature T as given in the kinetic theory of gases; in this paper it represents the combined velocity produced by thermal motions of the atoms and turbulent motions such as were postulated by Struve and Elvey[8] to explain curve-of-growth phenomena for supergiant stars, and is called the turbulent velocity.

Menzel[9] and Unsöld[2] have published families of curves which represent the relation between $W/\lambda.c/v$ and X_0 for all intensities

[7] *Ap. J.*, vol. 99, p. 249, 1944.
[8] *Ap. J.*, vol. 79, p. 409, 1934.
[9] *Pop. Astron.*, vol. 47, p. 66, 1939.

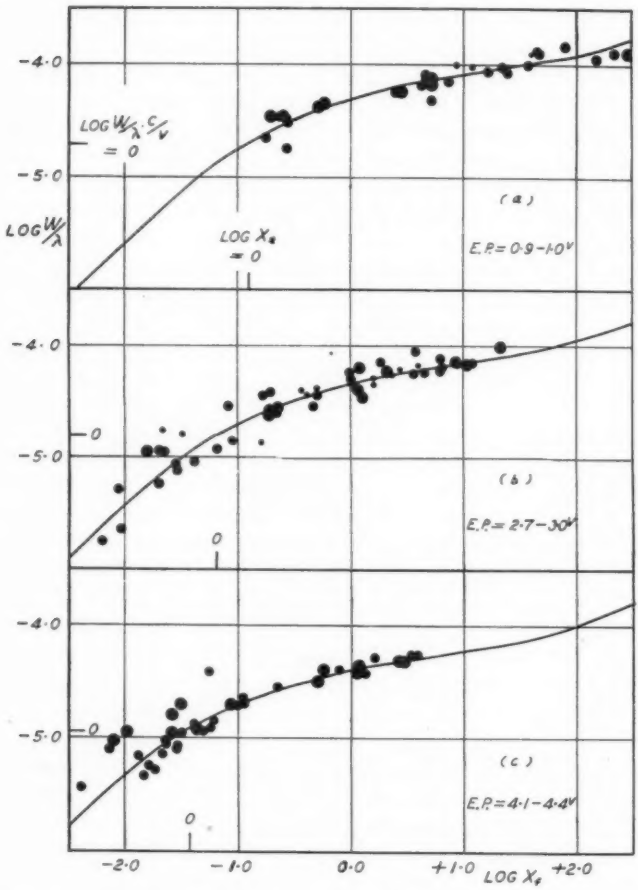

FIG. 2. Curves of Growth for Neutral Iron Lines in the Spectrum of α Persei. The theoretical curve, for which log $(W/\lambda \cdot c/v)$ is plotted against log X_*, has been superposed to give the best fit with the observational data, where log W/λ is plotted against log X_f, for three ranges of excitation potential. The theoretical curve has been shifted both vertically and horizontally from one diagram to the next; these shifts correspond to changes in the turbulent velocity, and the excitation temperature respectively.

and for a series of values of Z, which is directly proportional to the damping constant, Γ, and inversely proportional to the velocity v. The theoretical curve drawn in figure 2, which is the same curve in each case, though in a different position for each diagram, has an adopted value of $\log Z = -1.3$; this value was chosen after it had been shown that the value of Z did not change appreciably with excitation potential for neutral iron lines in α Persei. Any small variation in Z is unimportant in the curve of growth for this star as its effect is observed only for the very strongest lines, with large values of X_f.

In explanation of figure 2 it may be noted that the theoretical curve is constructed by plotting $\log(W/\lambda.c/v)$ against $\log X_0$ according to formulae derived by Menzel.[1] In the case of the plotted points, the ordinate is $\log(W/\lambda)$, an observed quantity, and the abscissa is the value of $\log X_0$ read from the solar curve of growth.[7] When the plot for a small range in excitation potential (*e.g.*, E.P. = 0.86 − 1.01 volts as in figure 2a) is placed on the theoretical curve, it is necessary to shift the graph in both vertical and horizontal directions. The shift in the ordinates in this case is 4.71, which is the value for $\log c/v$. As c, the velocity of light, is 3.0×10^5 km./sec., $\log c = 5.48$; therefore $\log v = 0.77$ and $v = 5.9$ km./sec., which is the value listed in Table I for this excitation potential. The difference in the abscissae, $\log X_*/X_f$ is 0.90 for the average excitation potential, 0.96 volts. Therefore, as marked in figure 2a, $\log X_* = 0$ is placed at the position $\log X_f = -0.90$. This quantity is related to the excitation temperature and will be discussed further under that heading.

The significance of these shifts from the point of view of the present paper is that they have different values for each small range of excitation potential. In order to illustrate this point the zero positions for each co-ordinate of the theoretical curve have been indicated in figure 2. It is seen that the shift of the ordinate varies from −4.7 for E.P. = 0.9-1.0 volts to −4.9 for E.P. = 4.1-4.4 volts; the shift in the abscissa varies from −0.9 to −1.4 for the same ranges in excitation potential. The turbulent velocities to which these marks correspond, the values for $\log(X_*/X_f)$ and the total weight of the lines in each group are listed in the successive columns of Table I for the ten ranges of excitation potential which were

TABLE I. TURBULENT VELOCITIES FROM *Fe I* LINES IN α PERSEI

E.P. Volts	v km./sec.	log X_*/X_f	Wt.
0.04	7.0	+0.52	25
0.96	5.9	+0.90	68
1.55	6.0	+0.94	55
2.21	5.2	+1.02	58
2.49	4.8	+1.05	69
2.87	4.6	+1.18	100
3.34	3.7	+1.25	89
3.80	3.7	+1.33	53
4.27	3.6	+1.42	93
4.63	3.6	+1.44	56

studied in α Persei. The variation in v from 7.0 to 3.6 km./sec., which corresponds to a change of 0.30 in the logarithm, is greater than the uncertainty of each determination, which is about 0.05 in the logarithm. The fact that v decreases progressively as the excitation potential increases tends to confirm the belief that this effect is real. Further confirmation is obtained when the results for other stars are included.

EARLIER VICTORIA MEASURES FOR SOLAR-TYPE STARS

In a forthcoming paper by the writer,[10] the intensities of approximately 800 lines in the spectra of the sun, γ Cygni, α Persei and α Canis Minoris are analyzed. The measurements, which were studied first in 1940, are based on the central intensities and the widths of the lines at the continuous spectrum. They are not as accurate as the intensitometer measures of α Persei which are discussed above, but the principal results obtained from them are not seriously affected. The lines of neutral iron were studied in the same manner as in the previous section and the results are presented in Table II.

The values for both the turbulent velocity and $\log(X_*/X_f)$ for the sun do not show any real change. This is a satisfactory result as the measures were made to test the accuracy of the Victoria equivalent-width measurements. It is unlikely that there will be

[10] *P. Dom. Ap. O.*, vol. 8, no. 1.

TABLE II. TURBULENT VELOCITIES FROM *Fe I* LINES IN SOLAR-TYPE STARS

	Sun			γ Cygni		
E.P Volts	v km./sec.	log X_*/X_f	Wt.	v km./sec.	log X_*/X_f	Wt.
0.05	1.9	+1.81	36	8.0	+0.63	29
0.95	1.7	+1.93	68	7.2	+0.97	63
1.54	1.8	+1.93	55	6.7	+1.03	60
2.28	1.5	+2.12	116	5.2	+1.25	99
2.80	1.9	+1.87	156	4.8	+1.32	146
3.34	1.9	+1.75	128	4.4	+1.32	118
4.04	1.7	+2.06	50	4.6	+1.32	48
4.61	2.2	+1.81	45	4.0	+1.45	45
	α Canis Minoris			α Persei		
E.P. Volts	v km./sec.	log X_*/X_f	Wt.	v km./sec.	log X_*/X_f	Wt.
0.05	4.0	+0.39	37	7.9	−0.01	30
0.95	3.3	+0.77	69	6.7	+0.40	63
1.54	3.1	+1.00	59	6.4	+0.51	55
2.28	2.0	+1.49	111	4.2	+1.03	95
2.80	1.7	+1.67	151	3.5	+1.13	137
3.34	2.2	+1.32	132	3.8	+0.80	115
4.04	1.6	+1.93	49	2.9	+1.38	50
4.61	2.7	+1.55	41	2.5	+1.59	42

any great difference between line intensities measured on spectra taken in integrated sunlight and those taken at the centre of the sun's disc, as Houtgast[11] has shown that the equivalent widths change slowly, except at the extreme limb of the sun. The variation in the turbulent velocity for the dwarf, α Canis Minoris, is somewhat less than that for the supergiants, γ Cygni and α Persei, which may indicate that the phenomenon is the result of some stratification in these stellar atmospheres. That there is a real variation may also prove interesting since α Canis Minoris is a dwarf similar to the sun in absolute magnitude.

RESULTS FOR OTHER STARS OF CLASS F

Measurements of line intensities obtained from spectrograms taken with the Coudé spectrograph attached to the 82-inch

[11] *Diss. Utrecht*, 1942; review in *Ap. J.* vol. 99, p. 107, 1944.

McDonald telescope have been published for two other stars: α Carinae by J. L. Greenstein[12] and δ Canis Majoris, for which the measures were made by J. O'Keefe and the analysis by Miss H. R. Steel.[13] Although there are not as many measures of neutral iron lines for these stars as for those already discussed, the changes in the derived turbulent velocity observed at Victoria should also appear for these stars if they are real. The published measures were grouped according to excitation potential and again log (W/λ) was plotted against log X_f for each line in a group. After each plot had been compared with the theoretical curves of growth, a mean value of Z was adopted for each star. Turbulent velocities and $\log(X_*/X_f)$ representing the shift in the ordinate and abscissa, respectively, when theoretical curves are fitted to the observations, are given in Table III; the measurements were given weight 2 unless the authors

TABLE III. TURBULENT VELOCITIES IN α CARINAE AND δ CANIS MAJORIS DETERMINED FROM *Fe I* LINES

	α Carinae				δ Canis Majoris		
E.P. Volts	v km./sec.	log X_*/X_f	Wt.	E.P. Volts	v km./sec.	log X_*/X_f	Wt.
0.05	3.3	+0.10	9	1.18	8.2	+1.76	18
1.54	3.3	+0.62	24	2.35	6.3	+2.26	16
2.34	3.3	+0.28	22	3.28	5.1	+2.23	36
2.83	2.7	+0.73	36	4.35	4.3	+2.75	30
3.43	2.2	+1.08	24				

listed them as uncertain, when weight 1 was assigned to a line. Again there is a definite decrease in the value of v with increasing excitation potential, and also a progressive change in log (X_*/X_f).

α Carinae is listed as a supergiant F0 star of intermediate luminosity, with absolute magnitude about −3.8, but the sharpness of its lines and the low values for the turbulent velocities make it comparable to α Canis Minoris; the small variation in the turbulent velocity with excitation potential is also similar to Procyon. These similiarities between a supergiant star and a dwarf may have a bearing on turbulent-velocity phenomena since it has usually been assumed that giant stars of this spectral class have broader lines

[12] *Cont. McDonald O.*, no. 43; *Ap. J.*, vol. 95, p. 161, 1942.
[13] *Cont. McDonald O.*, no. 113; *Ap. J.* vol. 102, p. 429, 1945.

and higher turbulent velocities than dwarfs. δ Canis Majoris, on the other hand, is a highly luminous supergiant star of class F8 and visual absolute magnitude -7.0. The turbulent velocity for lines of low excitation potential is higher than that for the other stars, but the range in v is about the same as for other supergiants.

Excitation Temperatures for Stars of Class F

The physical interpretation of shifts along the axis of ordinates (figure 2) with excitation potential as due to changes in turbulent velocity has already been discussed. There remains a consideration of the shift along the log X_0-axis, represented in the tables by $\log(X_*/X_f)$. These data may be related to the excitation temperature by a slight modification of the present theory, *viz.*, by allowing v to vary with excitation potential. X_0 has been defined by equation (2). Taking logarithms; denoting the data for the sun by the subscript $\odot$ (except for X_0 where the subscript f has been used); and subtracting those from the same data for the star (which are denoted by the subscript $_*$), we obtain the equation

$$\log\frac{X_*}{X_f} = \log\frac{N_*}{N_\odot}\frac{b(T_\odot)}{b(T_*)} - \log\frac{v_*}{v_\odot} - 5040\chi_i\left(\frac{1}{T_*} - \frac{1}{T_\odot}\right) \quad (3)$$

The first term in the right member may be considered a constant for a given atom—neutral iron in this case; let it be called D. Then equation (3) may be modified to read

$$\log\frac{X_*}{X_f}\frac{v_*}{v_\odot} = D - 5040\,\chi_i\left(\frac{1}{T_*} - \frac{1}{T_\odot}\right). \quad (4)$$

The solar turbulent velocity, as defined in this paper, has been adopted as 1.6 km./sec.; the excitation temperature for the sun, derived from the laboratory intensities of neutral iron lines published by King and King[14] is 4850°K. This equation is represented by figure 3, where $\log(X_*/X_f.v_*/v_\odot)$ has been plotted against χ_i for the stars α Persei, γ Cygni, α Canis Minoris and δ Canis Majoris. Least squares solutions were made to determine the slopes of the best straight lines which could be drawn through these observations, and from these solutions the excitation temperatures and their probable errors were derived. The results for the stars studied in this

[14] *Ap. J.*, vol. 87, p. 24, 1938.

TABLE IV. TEMPERATURES OF F-TYPE STARS

Star	Spectrum	Date	Excitation Temperature		Effective Temperature
			v variable	v constant	
			°K	°K	°K
α Persei	cF4	1945	5350 ± 125	4950	6650
Sun	dG2	1940	4800 ± 150	5100	5700
α Canis Minoris	dF3	1940	6100 ± 275	5250	6850
γ Cygni	cF7	1940	5250 ± 100	4600	5850
α Persei	cF4	1940	5850 ± 275	5000	6650
α Carinae	F0	1941	5950 ± 500	4900	7500
δ Canis Majoris	cF8	1941	6000 ± 350	4400	5600

paper are given in Table IV. Excitation temperatures for the stars studied at Victoria, derived from curves of growth in which v was considered constant and the temperatures published for the stars studied at the McDonald Observatory, are included in the table, as well as the effective temperatures for these stars as given by Kuiper.[15] It may be noted that when the turbulent velocity is allowed to vary, the excitation temperatures are appreciably higher than when it is considered constant but they are lower than the effective temperatures. The differences are not as great as those previously calculated, and they may be partially a result of the low excitation temperature adopted for the sun.

In this connection it should be mentioned that the turbulent velocity of the sun may also be found to vary with excitation potential when observations of the highest accuracy are employed. In that case it would seem probable that its excitation temperature would be increased. This effect is difficult to detect because there are relatively few laboratory intensities available for lines on the transition portion of the curve of growth for the sun. It may prove to be related to the discrepancies already noted[7] between theoretical and observed curves of growth for the sun, *viz.*, the shoulder of the empirical curve connecting the Doppler and transition portions is above the the theoretical curve and that connecting transition and

[15] *Ap. J.*, vol. 88, p. 429, 1938.

damping portions is below the theoretical curve.[16] Such a change in v might modify the present observations by requiring small corrections to X_f but would not vitiate the results.

Discussion of the Results

The present theory of the curve of growth is undoubtedly oversimplified. The Schuster-Schwarzschild model for a stellar atmosphere, on which Menzel's development is based, assumes that the photosphere is a definite radiating surface, which forms the continuous spectrum and that the absorption lines are produced in the surrounding atmosphere. It also assumes that the centre of the line is completely black and that only lines arising from the ground state, where the lifetime is long, are considered. No satisfactory theory for subordinate lines, arising from other levels, or for more complex models of stellar atmospheres has been published yet[17] though Unsöld[2] allows for some re-emission in the centre of the line by including a factor $1/R_c$ which appears in each co-ordinate of his published curves of growth. According to the observations made by Houtgast,[11] who traced the variation in the profiles of Fraunhofer lines across the surface of the sun's disc, it may be necessary to apply the theory of non-coherent scattering, which arises when selectively scattered radiation is first captured in the usual way and is subsequently re-emitted with a slightly different frequency, to the theory of line profiles. However, Spitzer[18] has pointed out that even in this case the theory of the curve of growth should not be changed greatly as it is based on the total intensity of the line; but, more important Struve[19] has pointed out that a far-reaching modi-

[16] This same difference between observed and theoretical curves of growth has been observed in the spectrum of Arcturus by Miss Suzanne E. A. van Dijke, who also remarks that it is apparent in Aller's curve of growth for Sirius (*Ap. J.*, vol. 96, p. 328, 1942). A copy of this interesting paper (*Ap. J.*, vol. 104, p. 27, 1946) was kindly sent to the writer by Dr. Struve while it was in proof.

[17] B. Strömgren's study of the composition of the solar atmosphere (*Festschrift für Elis Strömgren*, Munksgaard, Kopenhagen, 1940) is a moderately satisfactory approach to such a model stellar atmosphere, however.

[18] *Ap. J.*, vol. 99, p. 1, 1944.

[19] *Cont. McDonald O.*, no. 125, Ap. J., vol. 104, p. 138. 1946. The writer wishes to express his appreciation to Dr. Struve for sending him a manuscript copy of this important paper in advance of publication.

fication of the theory of the curve of growth may be necessary to reconcile turbulent velocities for δ Canis Majoris derived from line profiles and from curves of growth.

The earlier *Contribution*,[3] where it was noted that in α Persei lines of neutral and ionized atoms require separate curves of growth, with a larger value for the turbulent velocity for the ionized

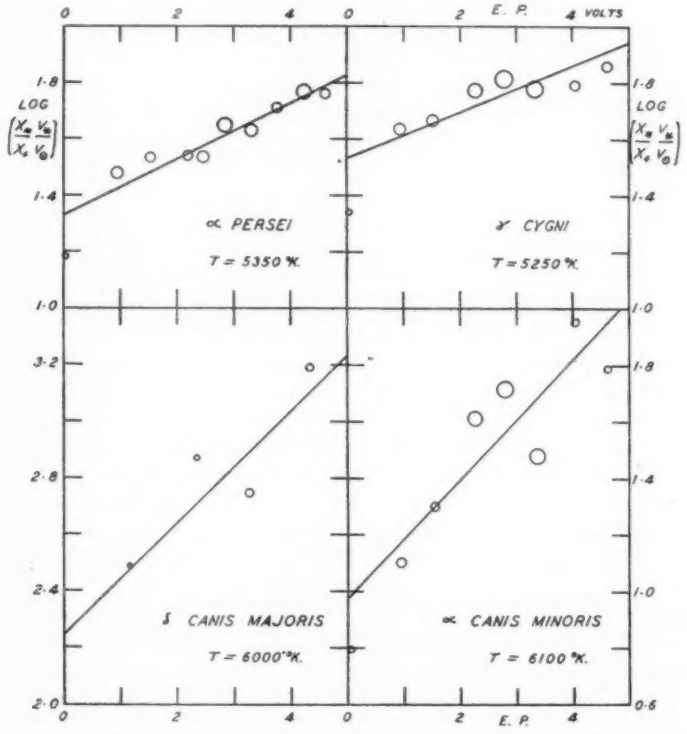

FIG. 3. Excitation Temperatures of Stars of Class F. The abscissa is the excitation potential, χ_i. The ordinate, $\log \frac{X_\odot}{X_f} \frac{v_*}{v_\odot}$ includes both the variable turbulent velocity and the temperature shift observed in Fig. 2. The larger circles represent points of greater weight.

atoms, contained the suggestion that there might be appreciable stratification in the atmosphere of this supergiant star. The findings of the present paper, that the turbulent velocity also varies with the energy level from which the lines arise, not only for α Persei but for other stars of class F, tend to confirm this suggestion. It will be made to appear still more probable if the effect can be observed for the sun, as noted above. It is known from flash spectra that the arcs of low energy-level lines extend higher into the sun's atmosphere than those of high energy-level lines from the same atom, and it has been observed[20] that the turbulent velocity increases with height in the solar atmosphere.

The excitation temperatures determined in the previous sections cannot, of course, be considered true temperatures since the atmosphere cannot be considered in thermodynamic equilibrium if the effect is a result of stratification of the atoms. Adams and Russell[21] suggested that a curvature in the straight-line relation between the number of atoms and excitation potential (similar to the diagrams of figure 3) would indicate a departure from thermodynamic equilibrium. However, except for the low value for lines of lowest excitation potential in each diagram, no systematic departure from a straight line is observed. Therefore, on the basis of the present theory, these results may be taken to represent some mean temperature related to the levels from which the spectral lines arise.

The result that the turbulent velocity, as determined from the curve of growth, varies with excitation potential is related directly to an alternative suggestion put forward by Struve[19] that the turbulent velocity is an increasing function of the equivalent width. Lines of low excitation potential are, in general, more intense than lines of high excitation potential. Therefore, if the turbulent velocity increases with equivalent width, it follows that the turbulent velocity found for low-level lines will be greater than that for high-level lines. To test the alternative suggestions, the true profiles of strong and weak lines having the same excitation potential should be determined from spectrographs employing the highest possible resolving power. The two methods of approach are completely

[20]ten Bruggencate, *Viert. A. G.*, vol. 76, p. 172, 1941.
[21]*Ap. J.* vol. 68, p. 9, 1928.

different and the results were reached independently. It is hoped that some means will be found of adapting the theory more completely to this new, and probably important, phenomenon.

Dominion Astrophysical Observatory,
Victoria, B.C.
July, 1946.

INTERESTING ATTACHMENTS FOR THE TELESCOPE

By F. K. Dalton

UNDOUBTEDLY many of the industrious members of the Royal Astronomical Society have at some time conceived ideas of attachments for their telescopes which would add unique features unobtainable with standard equipment and attachments. Probably they have been able to realize these in material form and could explain their ideas and designs, and narrate their experiences for the benefit of other members of the Society.

With this thought in mind, the writer would like to describe three new attachments which, with the assistance of good friends, he has been able to build for an Alvan Clark 4-inch refracting telescope having tripod mounting with equatorial head, but no graduated circles nor clock mechanism.

Finding Venus in Daytime

The planet Venus is visible even in a small telescope at any time on a bright sunny day when it is above the horizon, provided it is not too close to the sun for safety to the eye in looking through the instrument, i.e. not within three or four degrees from the sun. The problem is to find Venus. To do this by means of a graduated circle in right ascension and a clock mechanism, with a telescope which is portable and mounted on a tripod, entails a lot of adjustment each time it is set up before the instrument is ready for use. A declination circle, graduated in degrees, is, of course, essential but does not present any difficulty.

As a simple means to locate Venus in right ascension, using the information given in the *Observer's Handbook*, the writer placed on the head of the tripod, in the equatorial plane and movable with the telescope, a semi-circular sun-dial with straight wire gnomon normal to the plane of the dial. This dial is graduated in hours and minutes, and the shadow of the gnomon always falls on, or very near to the 12 o'clock point when the telescope is pointed directly at the sun at any time of the day. To adjust in right ascension for Venus, one has only to turn the telescope so that the shadow of the gnomon falls on the

time at which Venus is scheduled to transit the meridian, whether the planet be in east or west elongation. This gives the position of Venus in right ascension, except for the correction of the equation of time which from about April 1st until September 15th is never more than six and one half minutes, i.e. 1.6 degrees, and may be neglected. At other times of the year, correction must be taken into account.

The finder of this Clark telescope has a field of five degrees in width so with the declination properly set and with the shadow of the gnomon set to the time of transit of the planet, Venus will be found within the finder and is readily drawn to the centre of the cross wires and will appear in the main telescope.

This is a very simple but definitely consistent means of locating Venus whenever it is above the horizon, and can be used also to locate the planet, Mercury, earlier in the evening than by waiting until it appears in the western sky, i.e. when this planet is in eastern elongations. It gives spectators quite a thrill to be shown Venus while the sun is shining,—the brighter the sun and more blue the sky the better it may be observed,—for they seem to think they are seeing the impossible,—a "star" in the sky in spite of the sunshine.

Locating Polaris at Noon

Blue skylight is definitely polarized in a circle in quadrature with the sun,—while the sun is shining above the horizon and for about one hour after it has set. This polarized region has a width of a few degrees and will include the North Star throughout the day at or near the time of the equinoxes.

By using a polarizing eyepiece, it then is possible to darken the sky and in this way to create a much greater contrast between Polaris and its background. This provides an improved condition for locating this star at noon if the sky be not cloudy, and will be most effective at the time of the equinoxes.

In this case, the equipment consists of a star diagonal with a Polaroid glass in front of the prism, thus analysing the light before it enters the eyepiece, which is very essential. The Polaroid is mounted in a cell which is turned to approximate position and inserted in the tube of the diagonal. It then is turned to best position by turning the diagonal.

This scheme is very effective and again provides a means of seeing a star while the sun is shining, especially good for the equinoxes, creating a thrill for spectators and quite a degree of satisfaction to the amateur observer who uses it.

Roof Prism as Star Diagonal

It is quite customary when showing spectators the moon and planets at high altitudes to use a star diagonal in the telescope merely as a matter of convenience,—to avoid the awkward position of the head when using the straight eyepiece to view high objects. These diagonals make use of total internal reflection in a right angle prism and the resulting image is erect vertically but reversed laterally, i.e. the top and bottom are relatively correct but the first-quarter moon appears to bulge to the left instead of to the right. This always seems to cause confusion in the spectators' minds and promotes a question as to the reason for this strange reversal. Such confusion, however, does not arise in viewing a planet as the direct view does not give sufficient detail to judge of the position of the celestial body, and no questions are asked.

The writer recently has had the opportunity to obtain a very excellent roof prism, a geometrical form which resembles the ordinary right-angle prism but the hypothenuse, instead of being a flat surface consists of two flat faces, cut at 90 degrees to each other, which reflect left rays over to the right, and vice versa, before they come to the eyepiece. Thus the image seen in the eyepiece is now normally orientated. The roof prism also retains that great advantage of the star diagonal of turning the rays out at an angle convenient for the observer, i.e. at 90 degrees or some other angle as may be desired. This correction in orientation of the moon is very much appreciated by spectators and they endeavour to recognize familiar markings and imaginary forms on the surface as they have visualized them before.

There does not seem to be any good reason for the roof prism not being supplied as a star diagonal in normal attachments to an astronomical telescope. It has not been used extensively in the past, however, due largely to its previous high cost of production in sufficiently good quality to use at high magnification and at the same time in sufficient quantity to supply it as standard equipment.

Conclusion

The three attachments described above have proven very interesting and even more satisfactory in use than was at first anticipated. The development of a new device, in this case an attachment, may result from the realized need of certain features in the operation of the telescope as in the first two cases mentioned here or may result from finding in one's hands a new device or part, i.e. a new form of prism, and realizing its potentialities in connection with other equipment as in the latter case, its application to a telescope.

Other members of the Society must surely have stunts, schemes or new devices which would interest the readers of the Journal or the members who attend the meetings. Could not more be heard of their ideas and activities so that others may learn what can be done to improve their instruments and render them more versatile?

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OUT OF OLD BOOKS

By Helen Sawyer Hogg

Halley's List of Nebulous Objects

In the *Philosophical Transactions of the Royal Society* for 1715, the astronomer Edmond Halley published a descriptive list of six "luminous spots or patches." He himself was responsible for first calling attention to the unusual qualities of two of the objects on this list.

These six objects still remain, and always will remain, as among the most important objects in the sky. It is rather curious that among the six is to be found a representative of each type of large nebula or system of stars which we know to-day.

The first on Halley's list, the great nebula in Orion, is the outstanding example of luminous diffuse nebulosity. The second on Halley's list, the great nebula in Andromeda is the best known representative of the great spiral nebulae, those systems of tens of millions of suns beyond our own galaxy. With a distance of three quarters of a million light years, this is the most distant object which the unaided human eye can see. Although Halley credits Bullialdus with its discovery, the first telescopic examination was made earlier, by Simon Marius in 1612, when he wrote his famous description that the light was "like a candle seen through a horn."

The third item in Halley's list is Messier 22, one of the largest and richest of the great globular star clusters. The fourth, Omega Centauri, and the sixth, Messier 13 in Hercules, are also well known globular clusters.

The "small obscure spot at the right foot of Antinous," a constellation now extinct, is the well known rich galactic cluster of stars, Messier 11, in Scutum.

Halley's conclusion about these objects is as brilliant as his prediction of the return of his comet for he says "since they have no Annual Parallax, they cannot fail to occupy Spaces immensely great, and perhaps not less than our whole Solar System."

We reprint here the version of Halley's list as given in the abridged volume of the *Philosophical Transactions*. Halley gives the positions of these objects with respect to the signs of the zodiac, the symbols of which are identified on page four of the *Observer's Handbook;* current positions, brightnesses, distances and other data for all these objects except Messier 11, are given on pages 72-74 of the 1947 edition.

From *The Philosophical Transactions* (From the Year 1700 to the Year 1720), Abridg'd. Vol. IV, p. 224, 1721.

VII. Wonderful are certain luminous Spots or Patches, which discover themselves only by the Telescope, and appear to the naked Eye like small Fixt Stars; but in reality are nothing else but the Light coming from an extraordinary great Space in the Aether; through which a lucid *Medium* is diffused, that shines with its own proper Lustre. This seems fully to reconcile that Difficulty which some have rais'd against the Description *Moses* gives of the Creation, alledging that Light could not be created without the Sun. But in the following Instances the contrary is manifest; for some of these bright Spots discover no Sign of a Star in the Middle of them; and the irregular Form of those that have, shews them not to proceed from the Illumination of a Central Body. These are Six in Number, all which we will describe in the order of time, as they were discovered, giving also their Places in the Sphere of Fixt Stars.

The first and most considerable is that in the Middle of *Orion's* Sword, marked with θ by *Bayer* in his *Uranometria*, as a single Star of the third Magnitude; and is so accounted by *Ptolomy, Tycho Brahe* and *Hevelius*: but is in reality two very contiguous Stars environed with a very large transparent bright Spot, through which they appear with several others. These are curiously described by *Hugenius* in his *Systema Saturnium* pag. 8. who there calls this Brightness, *Portentum, cui certe simile aliud nusquam apud reliquas Fixas potuit animadvertere:* affirming that he found it accidentally in the Year 1656. The Middle of this is at present in ♊ 19°.00, with South Lat. 28°¼.

About the Year 1661 another of this Sort was discovered (if I mistake not) by *Bullialdus, in Cingulo Andromedae*. This is neither in *Tycho* nor *Bayer*, having been omitted, as are many others, because of its smallness: But it is inserted into the Catalogue of *Hevelius*, who has improperly call'd it *Nebulosa* instead of *Nebula;* it has no Sign of a Star in it, but appears like a pale Cloud, and seems to send forth a radiant Beam into the North East, as that in *Orion* does into the South East. It precedes in Right Ascension the Northern in the Girdle, or ν *Bayero*, about a Degree and three Quarters, and has Longitude at this time ♈ 24°.00′ with Lat. North 33°⅓.

The Third is near the Ecliptick between the *Head* and *Bow* of *Sagittary*, not far from the Point of the Winter Solstice. This was found in the Year 1665, by a *German* Gentleman *M. J. Abraham Ihle*, while he attended the Motion of

Saturn then near his *Aphelion*. This is small but very luminous, and emits a Ray like the former. Its Place at this time is ♉ 4°½ with about half a Degree South Lat.

A fourth was discover'd by M. *Edm. Halley* in the Year 1677, when he was making the Catalogue of the Southern Stars. It is in the *Centaur*, that which *Ptolemy* calls ὁ ἐπὶ τῆς τοῦ νώτου ἐκφύσεως which he names *in dorso Equino Nebula* and is Bayers ω; It is in appearance between the fourth and fifth Magnitude, and emits but a small Light for its Breadth, and is without a radiant Beam; this never rises in *England*, but at this time its Place is ♍ 5°¾ with 35°⅓ South Lat.

A Fifth was discovered by Mr. *G. Kirch* in 1681, preceding the Right Foot of Antinous: It is of its self but a small obscure Spot, but has a Star that shines through it, which makes it more bright. The Longitude of this is at present ♉. 9°. *circiter*, with 17°⅛. North Latitude.

The Sixth and last was accidentally hit upon by M. *Edm. Halley* in the Constellation of *Hercules*, in the Year 1714. It is nearly in a Right Line with ζ and η of *Bayer*, somewhat nearer to ζ than η: and by comparing its Situation among the Stars, its Place is sufficiently near in ♍ 26°½. with 57°.00. North Lat. This is but a little Patch, but it shews it self to the naked Eye, when the Sky is clear, and the Moon absent.

There are undoubtedly more of these, which have not yet come to our Knowledge, and some perhaps bigger, but though all these Spots are in Appearance but small, and most of them but of few Minutes in Diameter; yet since they are among the Fixt Stars, that is, since they have no Annual Parallax, they cannot fail to occupy Spaces immensely great, and perhaps not less than our whole Solar System. In all these so vast Spaces it should seem, that there is a perpetual uninterupted Day, which may furnish Matter of Speculation, as well to the curious Naturalist as to the Astronomer.

Readers who are interested in reviewing the life of Halley are recommended to read the excellent article by N. T. Bobrovnikoff in the Scientific Monthly, Nov. 1942, vol. LV, pp. 439-446, (Perkins Observatory Reprint no. 30). For a more exhaustive account, readers may consult the volume "Correspondence and Papers of Edmond Halley" arranged and edited by E. F. MacPike, Oxford, Clarendon Press, 1932.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Isaac Newton—Personal Details of the Man

One is always pleased to learn little details in the life of a friend or of a person one admires. For many years Newton seemed placed on a lofty pedestal, far above the petty questions one would like to ask about him. L. T. More's biography *Isaac Newton* (1934) gave a fuller picture and showed that though Newton was very human there were no events in his life which could not bear the light of day.

Last year (1946) there was published a small volume entitled *Newton at the Mint*, by Sir John Craig, Deputy Master of the Mint. Newton's work at the Mint extended from 1696 to his death in 1727, and of this part of his life little was known. Indeed what had been published appears to have been full of inaccuracies. The author of this book had access to a multitude of original documents, and the numerous foot-notes on each page bear witness that he has endeavoured to base his statements on unquestionable foundations. Further, he is familiar with all the technical matter involved. The result is a satisfactory narrative which one can safely assume to be in accordance with the actual occurrences.

Our readers will be interested in the following quotations from the closing chapter which is entitled "Survey."

> Newton's mathematical and scientific pursuits continued during his employment at the Mint.
>
> In his office, concrete problems were handled with reasonable competence, in so far as no revision of accepted principle or unusual prescience was needed. . . . In general the questions that arose year by year in the Mint, or which were referred to him for advice, were settled with gumption.

> It was his habit also to resort to personal interview and oral discussion on any matters of dissension. Contractors, candidates for employment, inventors and other rapscallions, were all seen in this way, and much of the correspondence with the Treasury began with or was clarified by conversations with successive Lord Treasurers, or First Lords after the office was put in commission.
>
> Newton appears to have been a good judge and handler of men, and he had some magnetism which in many engendered an extraordinary regard and respect. Not an effusively affectionate man himself, he was a target for such affection from others.

But with all his faith in direct contact in cases of dispute, as a good bureaucrat he insisted on the preservation of clear and exact records, . . . and was zealous for the sanctity of precedent, though it were musty with years. A hundred years were to him no more than one day. . . .

His notes suggest that the technique of gold and silver assaying was novel to him at his apponitment, but his manual dexterity was so phenomenal that in little over a year he could measure the difference of fineness of silver in the Scottish coins with absolute accuracy.

Written exposition of his views he found difficult. . . . Composition occasionally started with a list of points to be covered; very occasionally, an early draft was fair copied by a clerk, before being cut about anew; but usually Newton plunged straight into his subject, writing, correcting and rewriting until it came out to satisfaction.

The handwriting is tiny, verging on the microscopic in corrections between the lines, a reflection of the short sight which he mentioned in 1689. It does not vary appreciably in size or steadiness in the thirty years spent at the Mint. And he seems to have written very fast.

His benefactions to individuals and societies were excessively generous, but Newton lived well. He kept two maids and a manservant, and was particular in his choice of them. In 1721 he paid over £20 a quarter for hire of his coach and two horses, besides £4 9s. 6d. for his driver's livery.

According to Çonduitt, Newton commonly dined out with friends or had them to dine, and the household lived in a handsome and hospitable manner without ostentation. Here are his orders for the solid part of a dinner, probably about 1713:

Fish. Pasty. Fricassy of chicken and a dish of puddens. Quarter Lamb. Wild fowl. Peas & Lobsters.

The picture that emerges is of a creature of human contacts, who managed varied business with diligence and a moderate efficiency, except when a theory interfered, but, outside science, did not set the course of events on any new bearing.

C. A. C.

MEETINGS OF THE SOCIETY

AT TORONTO

February 26, 1946—The Society met at 8.00 p.m. in the McLennan Laboratory; Mr. Barker presiding.

Six persons were elected to membership in the Society, viz:

Mr. Louis Levine, 820 Dundas Street West, Toronto

Mr. Alex Milne, 42 Pacific Avenue, Toronto

Mr. Charles Leslie Rumball, 12 Moir Avenue, Toronto

Mr. K. R. Stehling, 142 Albany Avenue, Toronto

Mr. Leonard M. Steinberg, 54 St. Patrick Street, Toronto

Mr. Daniel Grey Watt, Ontario H.E.P.C. Laboratory, Toronto

Flight-Lieutenant Rodion Rathbone, B.Sc., of the Division of Research and Development, Royal Canadian Air Force, Ottawa, was introduced by Dr. J. F. Heard. He then presented a paper on "Radar: What it is and how it works."

The development of radar began about 10 or 15 years ago with basic research in many countries on very high frequency (short-wave) radio transmission. Before the war started each of the major countries knew what the others were doing, and the results of their studies were pooled as is usual in scientific research. It was found that as the frequencies became higher, there was a tendency for the waves to follow the curvature of the earth less and less, and that more depended on the reflection of the radio waves from the ionosphere. As shorter wave-lengths were used the waves behaved more and more in the manner of light and the range was more nearly limited to the visible horizon. When it was learned that if the wave-lengths were sufficiently short they were reflected from metal objects, and if shorter still, from wood, buildings, etc., a military significance was seen in the studies and from then on all the activity went "underground."

Radar, a word coined from "radio detection and ranging," was used during the war to detect the approach of enemy aircraft, to fix positions of aircraft in flight within 200 or 300 yards, and in the search for submerged submarines. The principles of transmitting and receiving radar are very similar to radio, but the technique is entirely different, and the radar technician has built up his own unique vocabulary.

Range is measured by the echo principle, and can be determined very accurately providing very short intervals of time can be determined. In radar little pulses lasting two or three millionths of a second are sent out, giving a very high power pulse with low average power transmission. With an exceptionally accurate form of timing device, radar can measure positions to within

20 feet at a distance of 200 miles. To get the accuracy needed, the electronic cathode ray tube was employed. Radar can be used for gun-laying or in anti-aircraft predictors, but if the target is in view Navy men still prefer to use optical range finders for getting bearings.

Radar found many successful applications during the recent war. Stations set up around Britain gave warning of the approach of enemy aircraft and fighters could remain on the ground until the enemy was near. Had it not been for these early warning stations used early in the war, the R.A.F. would not have had enough fighters to patrol the whole area and would not have been able to have won the Battle of Britain. Radar was also used in pinpoint bombing operations, for area bombing, in providing beacons for homing aircraft, in controlling searchlights, in ground control of planes arriving at and departing from airfields, and to locate paratroops for the purpose of dropping supplies.

The speaker saw peace bringing a vast field for research in radar and its application to new uses. Recent experiments in sending radar signals to the moon have shown that radar can penetrate the ionized layer of the earth's atmosphere. The equipment used, however, was about 10 years old and was very similar to the early-warning sets used in Britain early in the war. Such radar echoes could check the moon's distance, but a very narrow beam would be needed to map the lunar surface. In the U.S. moon-radar tests the beam was 17° wide, the speaker said. A very powerful impulse would have to be sent out to get a minute echo back, and the possibility of receiving an echo from more distant bodies than the moon was considerably more remote, he added.

Fight-Lieut. Rathbone showed motion picture films as used in air force training which illustrated the principles and use of radar, and answered several questions from members and visitors. Asked whether radar was likely to replace astro-navigation methods for determining aircraft location, he replied that in his opinion "astro" would remain for many years as the basic method of obtaining a position-fix completely independent of anything on the ground. When atmospheric and magnetic conditions affect radio reception, the navigator could always fall back on "astro," he said.

Dr. D. W. Best thanked Flight-Lieut. Rathbone on behalf of the members for coming from Ottawa to present this address.

Mr. A. R. Clute, K.C., Vice-President of the Centre, spoke briefly on "Theatres of the Stars: Recollections of Visits to the Planetaria in New York and Philadelphia." He recalled visiting the Fels Planetarium in Philadelphia shortly after its opening in 1935. "I was so impressed that I returned next day for another lecture. The feeling is most realistic that you actually are looking at the sky, not a reproduction of it on a dome. The illusion of the depth of space is perfect." On a later occasion, he said, he visited the Hayden Planetarium in New York. Pointing out that so far there is no planetarium in Canada, nor any place in the British Empire, Mr. Clute said: "It seems that

at least one Canadian city ought to be able to afford a planetarium, even if the government had to be called upon to provide part of the funds."

At the close of the meeting, drawings of recently observed sun-spot groups made by Mr. Bert Topham, and also a collection of radar photographs, were displayed on the lecture table.

March 12, 1946—The Society met at 8.00 p.m. in the McLennan Laboratory, Mr. Barker presiding.

Miss F. Nora Dunbar, of Barrie and Toronto, was elected to membership.

The Recorder presented reports on the formation of a telescope makers' group, and on the membership committee. Mr. E. J. A. Kennedy, the General Secretary, said that the Society had completed arrangements to move its offices and library to 3 Willcocks Street.

Dr. J. F. Heard of the David Dunlap Observatory, then spoke on "How Far's That Star: How stellar distances are measured." The paper was in commemoration of the 100th anniversary of the death of Friedrich W. Bessel, the first astronomer to measure the distance of a star by the trigonometrical or parallax method. A synopsis follows:

Bessel, who died on March 17, 1846, spent his early youth as clerk-apprentice to a commercial firm in Bremen, Germany. Becoming interested in navigation through a boyhood desire to visit China, he was led to a study of mathematics and astronomy which he mastered without tuition of any kind. At 21 he was appointed as assistant at Lilienthal Observatory and two years later became professor of astronomy at Königsberg and later director of the Observatory there. His first astronomical work had to do with the standardizing of the reduction of measurements of position. From this he was led to the problem of determination of annual parallax which for some decades had been baffling astronomers.

Measurement of the parallax of a star involves determining its small change of position relative to the more distant stars due to the changing position of the observer as the earth moves in its orbit. Bessel chose the star 61 Cygni as being probably close to the sun by virtue of its great proper motion, and decided to use a heliometer for measuring the separation of this star from a neighboring star which was much more distant. Continuing his measures for about a year, he found that the separation ran through a cycle of changes which gave a value of about one-third of a second of arc, corresponding to a distance of about three parsecs, 10 light-years or 60 million million miles. A repetition of the work over the next two years confirmed his original result. This work was from 1839 to 1842.

Subsequent measurements of stellar distances by this direct or trigonometric method, nowadays using photography, have yielded distances for some thousands of stars. The direct method becomes impractical beyond about 50 parsecs and it is then necessary to resort to indirect methods. The most successful of these

is the method of spectroscopic parallaxes in which small differences in the spectra of stars of the same spectral class yield their real brightness. Comparing this absolute magnitude with the apparent brightness then gives the parallax or the distance. In this way distances up to about 1,000 parsecs can be measured with fair accuracy.

Another indirect method is that of dynamic parallaxes, applicable only to binary stars. Solution of the orbit of a binary yields stellar mass; the mass-luminosity relation then yields real brightness; comparison with apparent brightness yields parallax or distance.

Still another method is applicable to Cepheid variables. For these stars there is a relation between period and luminosity which permits determination of distance. This method has provided measures of stellar distances within the galaxy up to 6,000 parsecs, into the tens of thousands of parsecs for the globular clusters, and into hundreds of thousands of parsecs for the closer spiral nebulae. Moreover, it has provided the basis for estimates of distances into the millions of parsecs for the more distant nebulae.

However great the distances with which astronomy deals, it must be recalled that all the methods rely on the basic method first brought to realization by Friedrich W. Bessel.

After a question period, the meeting was adjourned.

March 26, 1946—The Society met at 8.00 p.m. in the McLennan Laboratory, Mr. Barker presiding.

Mrs. H. G. Dearborn, 18 Eastmount Avenue, Toronto, was elected to membership.

Dr. Helen S. Hogg presented a brief outline of current astronomical phenomena, and added that recent study of old astronomical literature in the Dunlap Observatory library indicated there were no brilliant Northern Lights in the 17th century. It appeared, she said, that the sun was very inactive from about 1579 to 1714.

Dr. H. S. Armstrong, professor of geology in McMaster University, Hamilton, addressed the Society on "Dating the Geologic Past: The Niagara Escarpment an Example." A synopsis follows:

Throughout historical time man has wondered about the age of the earth. The Brahmin of India considered it ageless and eternal. At the other extreme, Archbishop Ussher of Ireland in 1654 decided after a close study of the Scriptures that creation had taken place at 9 a.m. on October 26 in the year 4004 B.C. The unfortunate inclusion of this figure as a marginal note in the King James version of the Bible resulted in the belief that the man was a heretic who would assume more than 6,000 years for the formation of the earth and all its features, and the highly imaginative explanations given to many natural phenomena stifled geologic thought for more than a century.

Our present estimate is that geologic time goes back 2,000 to 3,000 million

years. What we consider as more recent geologic time may be said to go back 40,000 to 50,000 years, and is best measured by two methods which depend upon seasonal variation: tree-ring analysis, covering about 20 centuries, and varved clay analysis, covering 200 centuries. The spacing of the annual rings in trees is familiar to all, and the extension of this history backward is merely a matter of painstaking labour and careful record. The use of varved clays, developed by Scandinavian geologists, was brought to North America by Antevs. They are banded clays which were deposited in the lakes formed by the melting of glacial ice. They are composed of alternating layers of light and dark material, one pair, called a varve, representing a year's deposition. Thickness of the layers is dependent upon the climatic conditions of the year, so here again we can apply methods of correlation such as those used in counting tree-rings. A third method of measuring recent geologic time makes use of the rate of recession of waterfalls.

Measurement of more remote geologic time has been achieved, with varying success, in several ways. In the fifth century B.C., the Greek historian Herodotus observed the thin veneer of sediment left by the annual overflow of the Nile and deduced that the building of the Nile Delta must have taken many thousands of years. The late Prof. Charles Schuchert of Yale University, the world renowned stratigrapher, showed that 400,000 feet of sediments had accumulated on the earth's surface at different places and times. Determining the mean rate of deposition for the various sedimentation basins, and allowing for other factors, a total of 686 million years is reached for the time involved in the three eras later than the pre-Cambrian. It is also recognized that the time involved in the pre-Cambrian is two or three times as long as all subsequent geologic time.

Somewhat related is the method based on the amount of salt in the sea. Calculations show that nearly 5,000,000 cubic miles or 16×10^{15} tons of salt would be precipitated upon evaporation of all the oceans. All this salt has come from decomposition of rocks on the continents, from which it is carried into the oceans at the rate of about 160 million tons annually. Many variable factors enter into the final calculation but once again we can say we are dealing in millions of years.

Another method is based on the rate of erosion of the continents. Calculations show that the rivers of the U.S. carry 783 million tons of earth matter into the oceans every year. At this rate it would require 10,000 years before an average foot of material was removed from the country's entire surface, or five million years to lower the surface by 500 feet. But the rate of erosion has not been constant, and there is evidence that the mountain ranges have been eroded several different times during the geologic past. At best, by this method, we can only say the earth is very, very old.

The most recent and most effective method of age determination is on the basis of radioactive disintegration. Some substances, such as thorium and

uranium, undergo a slow decay during which the nuclei of the atoms lose alpha particles and electrons, forming new elements. Half of a given quantity of uranium would become lead in something like 5,000 million years—but this lead has an atomic weight of 206 instead of 208 like ordinary rock lead. By determining the amount of undecomposed uranium and the amount of lead 206 in a rock, the geologist can determine the age of the rock. Allowing for other variable factors, calculations of this nature have been made on many rocks, the oldest uranium-bearing rocks indicating an age of about 1862 million years. And these rocks cut across other rocks which are, therefore, even older.

In an article[1] on "Galactic evidences for the time-scale of the universe," Prof. S. Chandrasekhar of the University of Chicago shows that the galactic star clusters, the statistics of binary stars, the clusters of extra-galactic nebulae and the systems of the nebulae all agree in pointing to a time scale of the order of a few thousand million years. As he points out: "It does not seem that this can be accidental."

As an illustration of the immensity of geologic time, the Empire State Building in New York City is 1250 feet to the top of the mooring mast. A dime placed on edge on top of the mast would represent, in correct proportion to the height of the building, the duration of man's existence on earth relative to the duration of the earth itself. A dime placed flat on top of the other dime would represent, to the same scale, the historical record of man.

Recalling that one of the methods described depended on the accumulation of sediments, Dr. Armstrong cited the Niagara Escarpment as an example. Rock thicknesses at Hamilton show that, from lake level to the top of the mountain, there is 24½ feet of sandstone, 304 feet of shale and 167½ feet of limestone. Using Prof. Schuchert's figures for deposition of inland seas, deposition of the rocks of the escarpment would have required 490,000 years for the sandstone; 9,120,000 years for the shales, and 9,050,000 years for the limestone; a total of 18½ million years. These figures agree well with those determined by radioactivity studies of rocks of the same general period of time elsewhere.

The portion of the escarpment known as the Niagara Gorge is still more important. About a million years ago this part of North America saw the onslaught of ice from the north, ice which at one time was 3000 feet thick and which advanced and retreated no less than four times. Soon after the last ice melted away water began to pour over the escarpment at five places, all in the vicinity of the present Niagara River. One of these developed more rapidly than the others, gradually captured the bulk of the drainage and became a good-sized waterfall.

The first part of the gorge, 2000 feet long, was cut by the first of the five streams which is believed to have carried about one-quarter the volume of the present river. Southwards another mile and one-eighth is the second part, constituting the Old Narrow Gorge, cut by a river carrying about 15 per cent.

[1] *Science*, December—1944.

of the volume of the present Niagara—the drainage of Lake Erie alone. For two miles south again is the Lower Great Gorge through which flowed the drainage of the forerunners of the four Upper Great Lakes, hence about equivalent in volume to the present Niagara. The gorge of the Whirlpool Rapids is a narrow gorge extending south-eastward for three-quarters of a mile and representing a decrease in volume when for the second time only Lake Erie discharged through the old Niagara river. The fifth and final section extended 2¼ miles to the present falls, a wide section cut by the discharge of the four upper lakes.

Since 1841 several very careful instrumental surveys of the crest line of the Falls have been made and it has been possible to compute the average rate of erosion of the present volume of water, the amount ranging from 4.5 to 5 feet per annum. Combining these figures with the detailed analysis of the gorge over its entire length, and making certain other allowances, the figure of approximately 35,000 years has been arrived at to represent the length of time which has elapsed since the ice began to retreat in this area.

An open discussion period followed, and the President thanked the speaker for coming from Hamilton to address the meeting.

FREDERIC L. TROYER, *Recorder.*

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